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***Maritime Platforms Division**
Platforms Sciences Laboratory

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ABSTRACT

The Royal Australian Navy (RAN) operates several types of combat, minehunting and support ships, which employ steel and copper-nickel (CuNi) piping for mostly low-pressure fluid intake and discharge. The flowing media over time can either cause blockages or destroy the pipe integrity due to marine growth and subsequent corrosion of metal alloy. Maintenance due to corrosion in metallic pipe is therefore a significant issue faced by the RAN. The Defence Science and Technology Organization in collaboration with Tenix is assisting the RAN in investigating the use of Glass-Reinforced Plastic (GRP) piping technology as a solution to existing problems in metallic piping.

Manufactured GRP pipe products are inherently corrosion resistant in many difficult environments and are lighter weight when compared with steel and CuNi piping. In order to gauge the performance a project was initiated to trial the GRP pipe technology on HMAS Anzac. Prior to obtaining approval for a trial the GRP pipe technology was assessed for risk and compliance against technical requirements. The requirements of shock and fire were regarded not essential due to the non-critical nature of selected systems and their locations. However, such requirements are essential for critical systems and therefore would require qualification testing or equivalent on GRP piping.

This paper provides an overview of the selection of ship pipe systems for trial, technical challenges encountered during GRP pipe installation and cost comparison between metallic and GRP piping. Results after six months into the trial indicated the installed GRP piping in HMAS Anzac was in good condition with no report of visible signs of corrosion, condensation or cracking

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Executive Summary

The Royal Australian Navy (RAN) is continuously searching for solutions to reduce ship maintenance and decrease through-life cost. One of the several maintenance issues on board the RAN surface fleet is keeping piping systems healthy. Piping systems are predominantly metallic and used in transporting corrosive fluids such as seawater and oily waste water. Metallic piping is subjected to corrosion attack from flowing seawater and other corrosive fluids, and to blockage from accumulation of marine organisms found in the seawater. These problems cause systems to fail and require remedial action frequently thereby increasing through-life maintenance costs. The Maritime Platforms Division (MPD) of DSTO commenced exploring the use of non-metallic piping to address such issues, and in particular the use of the glass-reinforced plastic (GRP) piping technology.

Following the acceptance of the advice given by MPD to Anzac Sustainment Management Office on the potential benefits of GRP pipe technology, it was agreed to conduct a trial on an Anzac Class surface ship. Tenix Defence Systems Pty Ltd also participated in this trial due to their roles as the in-service support provider for the Anzac Class ships and as a participant in the DSTO-Tenix Industry Alliance. The reporting on the trial outcomes is covered under a Task sponsored by NAVSYSCOM.

This general document provides an overview of the problems in metallic piping systems on board Navy ships, the selection of ship piping systems for the trial, risk analysis conducted to obtain approval for a GRP pipe technology trial on a Navy combat ship, technical challenges with the GRP pipe installation on HMAS *Anzac*, cost comparison between metallic and GRP piping and some early trial outcomes describing the performance based on resistance to seawater corrosion, marine growth and outdoor elements.

Contents

1. Introduction

The Royal Australian Navy (RAN) operates several types of combat ships (Figure 1), and amphibious and support ships in its surface fleet. All these ships employ steel and copper-nickel piping in their platforms systems. The cost to RAN for fighting corrosion in metallic pipes is significant. The Defence Science and Technology Organization in collaboration with Tenix is assisting the RAN in investigating the use of Glass-Reinforced Plastic (GRP) piping technology in order to facilitate technical improvement and deliver cost advantage.

The glass-reinforced plastic (GRP) pipes available in nominal sizes up to 900 mm diameter, although increasingly used in non-military applications [1,2], have not had the same success in military applications due mainly to the stringent acceptance standards it has to meet. In order for the technology to pass the acceptance phase, risk analysis of the technology accompanied by a trial is of significant importance. A trial of the technology would indicate whether it makes a significant impact on the ship operational capability and ship maintenance costs.

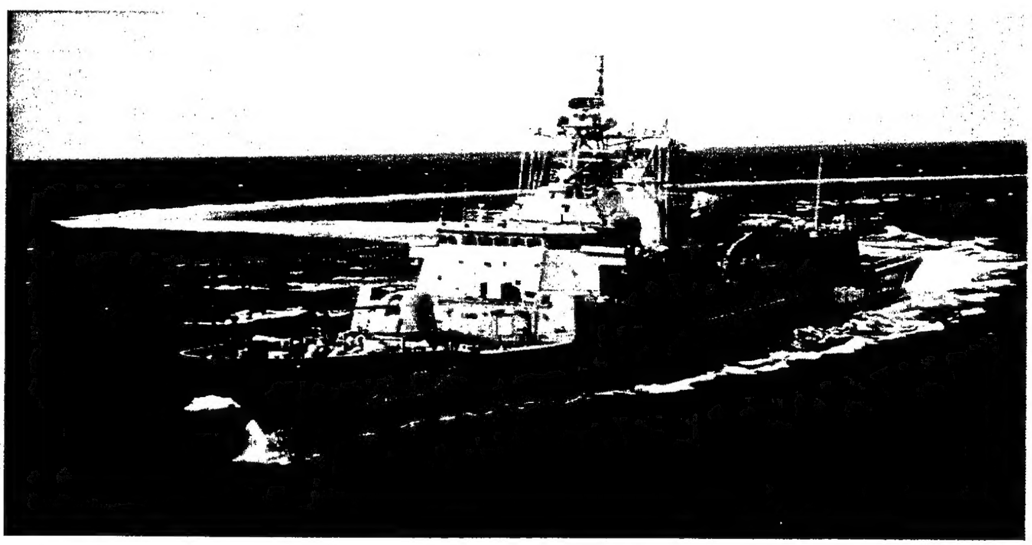

Figure 1: Royal Australian Navy's HMAS Anzac

2. Maintenance issues with metallic piping systems

Data collected from maintenance and service records indicate seawater (SW) corrosion and marine growth as the main causes of system failure in the RAN surface ships. The SW corrosion led to corrosion of pipe internal surface causing reduction in pipe-wall thickness and eventual pipework failure. The marine growth at internal pipe surface caused blockages, which led to system shutdowns. The affected piping systems onboard the RAN's surface ships were SW cooling, oily waste, sewage and magazine sprinklers. The sewage system has suffered recurrent and worsening frequency of blockages and the auxiliary SW system has also been found to be susceptible to flow reduction from marine growth. Another problematic system reported is the magazine sprinkling system. This system has CuNiFe piping up to entering the respective magazine. In the magazine the pipework is galvanised steel. It is reported that this pipework was replaced on a regular basis at significant cost to the Navy. The Navy has continually raised orders to replace existing pipework in the oily waste systems due to failing pipework.

3. Selection of ship pipe systems for the trial

A panel, comprised of staff from Maritime Platforms Division (MPD) of DSTO, Tenix and ANZAC Sustainment Management Office (ANZAC SMO), carried out the selection process in which several issues were raised. Each one of these was addressed so as to facilitate risk analyses and in the preparation of a risk matrix leading to gaining approval for a shipboard trial of a technical demonstrator. These issues and the agreed outcomes from the panel discussion were:

Nature and size of the system

The panel agreed that for performance comparison the ship pipe system should be non-critical and have shown a history of problems. In order to keep the costs low, preference was given to small systems, relatively localized in one area and not spanning across more than one compartment.

Environment

The priority system put forward for selection was the one in which aggressive fluids such as seawater and other corrosive fluids are transported. Although additives are available to make the pipes more resistant to these conditions, the panel decided that for the purpose of gauging the suitability of GRP piping and to gain a real

value from a trial there should be no protection provided for the pipes against corrosive environment.

Shock loading

Results from a study on the shock response of GRP pipe systems showed that 8 inch diameter pipes remained undamaged following exposure to shock [3]. Shock qualification of GRP pipes was not considered essential because the selected systems for this trial were non-critical. However, shock qualification of GRP pipes will be a critical issue and may be part of future studies. The study should include the shock qualification of GRP pipes against the Australian shock standard and BV 043 [4,5]. The above qualification against existing ship specification standards, plus engineering design input from piping manufacturers shall dictate for example the hanger spacing, which will need to be changed for retrofit installations.

Connection method

To limit the impact on existing and remaining pipework, it was determined that existing connection standards and equipment would have to be maintained where the GRP sections interfaced with the existing steel systems. GRP pipe manufacturers offer a range of standard GRP connection methods for piping in marine and naval systems [6] and exact interface connections were easily obtained. The issue of connection methods was therefore not a problem, however, connection details for either total or partial replacement of existing metallic piping need to be considered and recorded appropriately during installation.

Electrical continuity through the system

The issue of excessive accumulation of static electrical charges and the risk of discharge in shipboard use of GRP piping came into consideration in the discussion. The manufacturers of GRP piping offer fully grounded systems with conductive elements incorporated in pipe wall to overcome the stated risk. The panel accepted this provision against the requirement.

Fire rating

As with shock requirement this is another significant issue that had to be clarified prior to installation of GRP piping in locations such as engine room spaces or between watertight bulkheads. Fire endurance ratings issued by the regulatory authorities are available through pipe manufacturers for specific series of GRP piping and piping location but not against the specific requirements for Naval

Ships. This issue will have to be addressed through qualification trials for use in critical systems.

UV exposure

Degradation due to UV is considered an issue only for piping systems that are in outdoor locations, and was suggested to be one of the several performance indicators in this trial.

Pressure rating

Standard GRP pipes are tested and certified to the international marine standards for pressure levels higher than the required levels for selected systems in this trial.

Maintenance routine

The possibility of impact on the maintenance routine was discussed. No negative impacts were anticipated, but this is something that the ship staff will confirm during the trial.

Three non-critical pipe systems were chosen based on the issues above.

- **Provision plant salt water cooling pipework in 4K**

  Currently uses DN 32 CuNi pipe material and is exposed to seawater. GRP pipework to replace CuNi pipe material; the trial will provide comparison with CuNi pipe material in terms of corrosion resistance, resistance to marine fouling and condensation

- **Oily water waste system pipework in 4H**

  Currently uses DN 40 St 37 pipe material and is exposed to corrosive oily water and has a history of problems. GRP pipework to replace St 37 pipe material; the trial will provide a comparison with St 37 pipe material in terms of corrosion resistance

- **Outer deck drains on 02 deck**

  Currently uses galvanized steel pipes (76 NB, 2.6 mm wall thickness) painted in military gray. GRP pipework, 80 NB, to replace galvanized steel; the trial will test GRP pipework against sunlight (UV) exposure and colour matching capability

4. Risk analysis process

In determining the risks involved in using GRP pipe on an ANZAC ship, it was obvious that it would not be necessary to reconsider the risks inherent in operating standard pipe systems on Naval ships, as this was already allowed for in the specification and design of the ship in general and the pipe systems in particular.

The risk analysis for this trial was therefore based on a study of all the areas where the GRP pipe did not comply with the requirements in the ANZAC Ship Specification [7,8] and all referenced standards and material and system specifications. The areas of non-compliance were assessed through a standard Consequence and Likelihood Risk matrix process.

The ANZAC Ship Specification requirements applicable to piped systems can be separated into two groups namely, General Ship Requirements [7] and General Piping System Requirements [8].

4.1 ANZAC General Ship Requirements

The ANZAC General Ship Requirements [7] specify the following characteristics for all material or equipment to be installed on the ship, including piping systems:

- Material characteristics for toxicity, smoke generation, fire propagation and corrosion resistance;
- Shock and Vibration resistance and Noise reduction;
- Thermal insulation for machinery, equipment and piping systems.

The areas of non-compliance to these General Ship Requirements are given in Table 1 below.

Table 1: General Ship Requirements, compliance and risk assessment.

REQUIREMENT	COMPLIANCE	ASSESSED RISK
Shockproofness Grade B equipment which is not vital to the safety of the ship or its full combat capability must comply with referenced military standards. As a result of the shock load in accordance with these standards, detailed parts of items of equipment may not come adrift and hence create a hazard to crew members or equipment belonging to the higher Shockproofness Grade A.	Partially compliant - The exact compliance to the appropriate shock curves is not known. However, trials by TNO [3] in The Netherlands showed that 8" AMERON GRP pipe complied with the equivalent military standard.	Given the TNO [3} results, it was assumed that, at the very least, the smaller 4" diameter GRP pipe would not fail in such a way as to hazard a crewmember or damage Shock Grade A equipment. The trial systems were also not vital systems so that a shock failure would not affect the safety of the ship or its full combat capability. The consequence and likelihood of a GRP shock failure was therefore regarded as MINOR and UNLIKELY respectively, and the consequent risk rated as LOW.
The guidelines for fire resistance given in IMO Resolution A.753(18) provided acceptance criteria for plastic materials in piping systems. They also give appropriate design and installation requirements and, for each application, fire testing performance criteria necessary to ensure that vessel safety is adequately addressed.	Partially compliant - The US Coast Guard has certified both BONDSTRAND Series 7000M® and BONDSTRAND Series 2000M® GRP pipe in accordance with IMO Resolution A.753 (18). The pipes did however not meet the Flame Spread and Smoke requirements of this Resolution.	It was assessed that, in the case of fire, the flame spread and smoke generated by GRP pipe would be worse than for the original steel pipe installation. However, due to the small quantities of GRP pipe installed for this trial, the consequence and likelihood of it causing or making a fire any worse, can be regarded as MINOR and UNLIKELY, and the consequent risk rated as LOW

4.2 ANZAC General Piping System Requirements

The ANZAC General Piping System Requirements [8] detail requirements specific to piping systems on Naval ships, such as:

- Corrosion and erosion precautions through physical system layout and material selection and material combinations;
- Pipe system design, component selection and layout for general operability and damage control through redundancy and inter-compartmental flooding prevention and fire suppression.
- Structural requirements and supporting elements and spacing for shock, noise and vibration.

It was found that the GRP pipe sections used in this trial would not change the respective systems' compliance to the ANZAC General Piping System Requirements, because the compliance was inherent in the original designs of the systems.

It is important to note however that this would not be the case with all piping systems on the ANZAC Class ships. Shock Grade A systems will need a complete redesign of their general structure and supporting elements based on extensive shock testing of each individual pipe size, done to the original German shock standard, BV 043 [5]. Bigger systems will also require isolating valves where they penetrate bulkheads to prevent cross flooding or inter compartmental air flow through GRP sections that may have become damaged.

5. The GRP pipe installation - technical challenges

- **OILY BILGE SYSTEM**

The spools selected were part of the Bilge De-Oiler overboard discharge line. The selected spools, 90 elbows and tees of DN 40 were replaced by 40 NB, 5.5 mm thick Bondstrand Series 7000M® anti-static conductive GRE (E stands for epoxy) pipes, see Figure 2. Pipe connections to bend and tees were carried out using the Quick-Lock® adhesive joining technique [6]

All existing pipe brackets and mountings were used with the exception of one bracket on the vertical leg after the 3-way valve [Figure 2]. This bracket was not used due to the radius limitations on the GRP pipe. The task of installation was completed with minimal difficulty using no special tooling other than the trade specific tools.

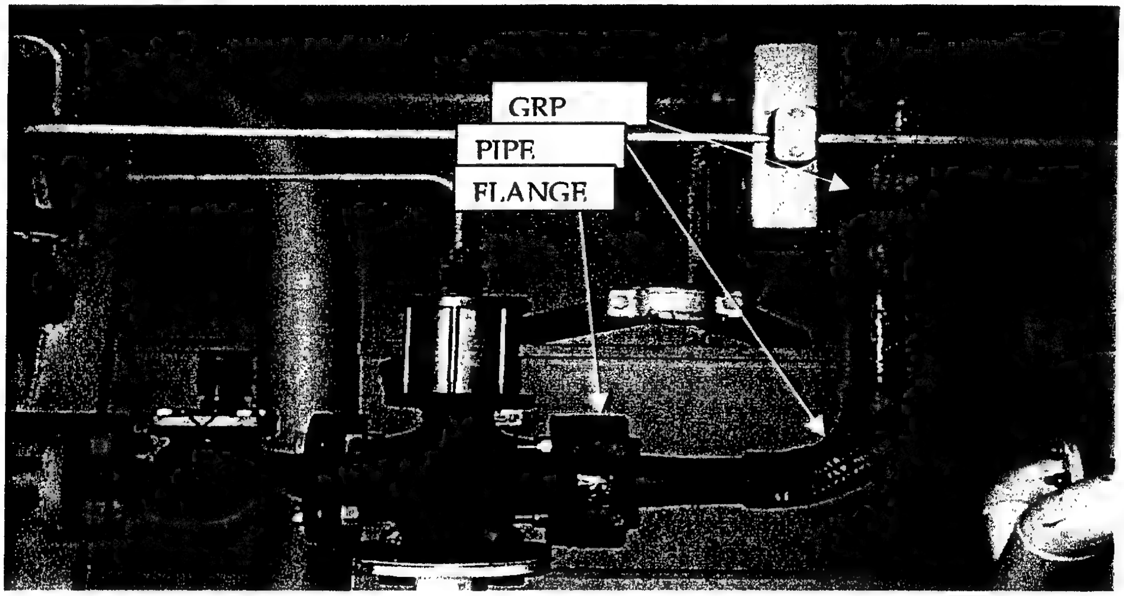

Figure 2: GRP piping for Oily Bilge piping system in HMAS Anzac

- **PROVISION PLANT SEA WATER COOLING**

The ship staff tagged the system, prior to the removal of the metallic pipework. The whole of the suction line, made up of two spools, 32 DN CuNi, from seawater strainer to the isolating valves just before the seawater cooling pumps was replaced with 40 NB Bondstrand Series 2000M® GRE pipes, see Figure 3. Deck plates were removed to gain access to the system. Metallic couplings comprising Pyplok Crimp with tail connections, were supplied to the subcontractor. The Pyplok Crimp part of the coupling connects to existing valves. The tail connection of the coupling was inserted into a 25 NB GRE pipe and joined adhesively using the same resin as that used to bond the GRE together. This method has proved very successful in the past. A piece of 50 mm wide skrim tape of woven fibreglass was wrapped around the base of the coupling and the top of the GRE pipe in a spiral, utilising a 50% overlap. The tape was impregnated with resin during the process. This gives added strength to the joint between the GRE and the tail connection of the coupling. The Quick Lock Adhesive joining technique was used for all other connections involving GRE pipe to GRE elbows, tees and reducers.

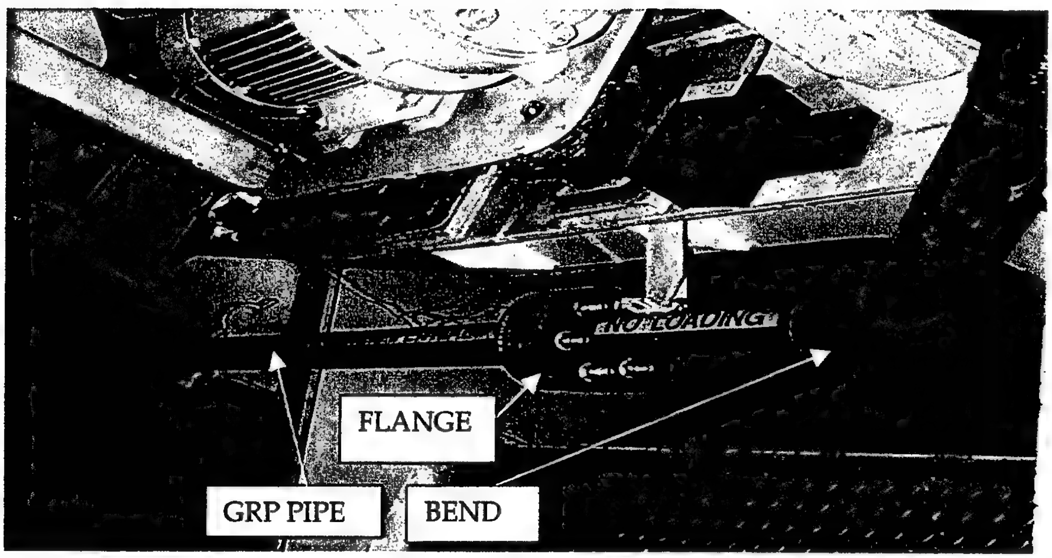

Figure 3: GRP piping for Provisional Seawater Cooling on HMAS Anzac.

The greater part of this system was pre-fabricated at the subcontractor's workshop from measurements taken from the removed original pipework. The fabricated GRP pipework was site measured, cut and glued then removed to the workshop for heat curing of joints and pressure testing prior to final installation.

All existing pipe supports and brackets were utilised however, longer bolts were required due to the larger outside diameter of the GRP pipes. Installed pipework was marked 'GRP Pipe Trial' and 'No Loading' due to its elevation and its proximity to a walkway.

The installation process was simple with no difficulties encountered. No special tooling was required to carry out this task other than the subcontractor's trade specific tooling. The installation process could be faster if all post-fabrication work is carried out at the shipyard site.

- **TBD 02 DECK DRAIN**

An outer deck drain pipe was selected for this trial. This drain pipe is located on the starboard side of 01 Deck Zone. The galvanized steel pipe was cut approximately 50 mm from the base of transition section at the top of the drain. A new length of 80 NB Bondstrand Series 5000M® GRP pipe was bonded to the remaining pipe stub on site, see Figure 4. Existing brackets were utilised however, the installation required longer bolts due to the larger diameter of GRP spool.

This was a very simple installation. All the work was carried on site and required no special tooling other than trade specific tools.

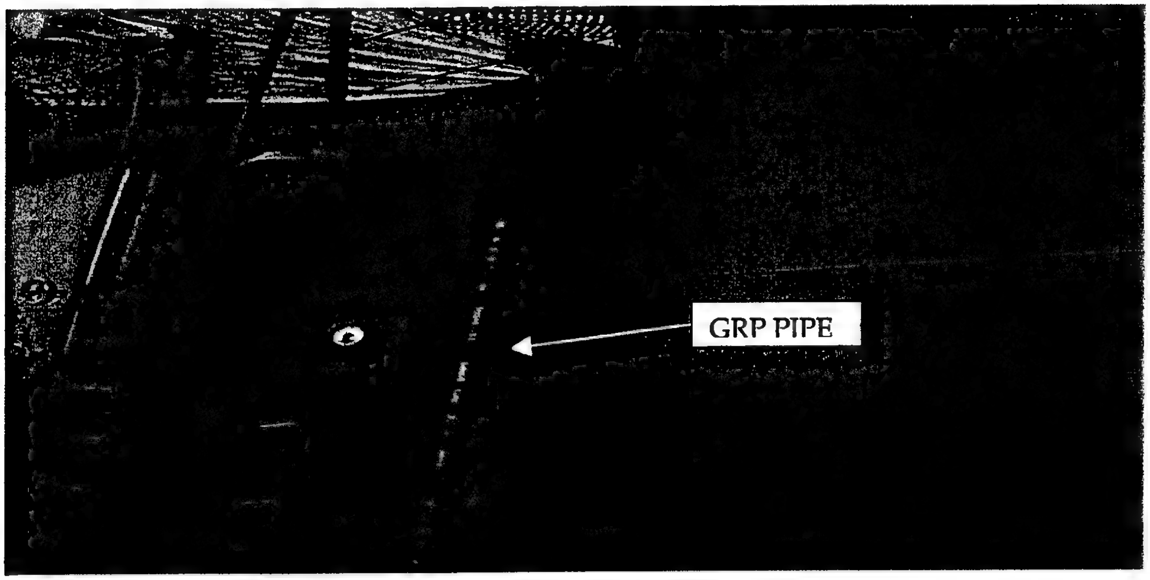

Figure 4: GRP piping for Outer Deck Drain on HMAS Anzac.

6. Cost Comparison - Metallic versus GRP

Table 2 gives an indicative comparison between GRP pipes and metallic pipes in terms of material and fabrication and installation costs. Material costs for GRP pipes were significantly greater than costs for metallic pipes. This is because small quantities of GRP pipes were ordered for the ship trial whereas costs for metallic pipes were estimated from the price based on a bulk order. It is anticipated that bulk orders of GRP pipe material would bring the cost down significantly, however, the costs may still be 30-40 % above metallic pipe material.

In Table 2 the high costs for fabrication and installation of metallic pipes include the costs of pre-installation engineering such as welding and placing pipe support hangers and valve attachments. The GRP pipe installation was carried out using most of the existing engineering arrangement hence the costs incurred are significantly less in comparison. The fabrication and installation costs will rise with the inclusion of the engineering work however the overall costs may not exceed those for metallic pipe. One of the well-known advantages of GRP pipes is that neither welding nor specialised tooling are required for their installation.

Despite the initial material cost disadvantage, the use of GRP piping may provide significant through-life cost-savings due to reduced frequency of pipe maintenance and repair.

Table 2. Costs comparison of GRP and Metallic pipes.

Pipe System	**Fabrication and Installation (Hours)**		**Other (Hours)**		**Fabrication and Installation Costs ($)**		**Other Costs ($)**		**Material Costs ($)**		**Total Costs ($)**	
Provisional Seawater Cooling	GRP	CuNi	GRP	CuNi	GRP	CuNi	GRP	CuNi	GRP	CuNi	GRP	CuNi
	32	92	16	14	2176	5980	1088	910	4974	730	8238	7620
Oily Waste Water	GRP	St 37	GRP	St 37	GR	St 37	GRP	St37	GRP	St37	GRP	St37
	28	58	11	9	1904	3770	748	585	3743	110	6395	4465
Outer Deck Drain	GRP	St 37	GRP	St 37	GRP	St 37	GRP	St 37	GRP	St37	GRP	St37
	-	30	-	4.5	-	1950	-	292	450	50	450	2292

7. Preliminary trial outcomes

Installation of GRP pipes in HMAS *Anzac* was completed in July, 2002. The trial monitoring commenced soon after with the focus on gauging the resistance of installed GRP pipes to:

(i) seawater environment (corrosion and marine growth)
(ii) surface condensation and
(iii) outdoor elements

Seawater Environment

The piping has been subjected to a range of environmental conditions. Initially the piping was exposed to Western Australian winter maritime conditions over the period Aug–Oct 02. Currently, HMAS *Anzac* is deployed to a mid-latitude Northern Hemisphere winter. Depending on the area and time of year, the sea temperature has been as high as 26°C and as low as 16°C. High humidity was evident at the start of the deployment (Nov 02), however by mid-winter it has become dry. It is expected that the humidity will become extreme as the season changes from winter to spring.

Pipe Surface Condensation

Visual inspections were carried out weekly for surface condensation on the pipes in 4 Hotel and 4 Kilo sections. The condensation is classified as light (of no concern), both sets of piping remained totally free of condensation since installation. The appearance of the piping had not changed after six months.

The machinery spaces experienced high humidity and temperatures during the start of the current deployment and the pipes were still free of condensation. As the outside temperatures and humidity rise with the change in seasons, ship's staff will continue to monitor and report whether the condensation develops on the pipe surface.

Resistance to Outdoor Elements

The outdoor pipe has not changed in appearance. There seems to be no cracking with exposure to sunlight, and no changes in colour/gloss, surface chalking and surface craze. The changes therefore can be classified as light.

8. Conclusions

In order to establish confidence in the use of the GRP pipe technology for naval application, a project was initiated to trial the technology on the RAN combat ship, HMAS *Anzac*. After carrying out risk analysis and compliance assessment against naval ship standards, three non-critical systems namely, provisional seatwater, oily waste water and outer deck drain, were selected for the trial. Technical requirements of shock and fire were not regarded as essential due to the non-critical nature of the systems and their locations. However, such requirements are essential for critical systems and would require qualification testing or its equivalent, of GRP piping. The trial on HMAS *Anzac* is still in progress however results after six months of trial are very encouraging. The GRP piping installed appeared in good condition with no visible signs of wear and tear, corrosion, condensation or cracking. The pipes have not been of concern to ship's staff even during active duty in the Persian Gulf and there has been no corrective maintenance required on the piping.

9. Acknowledgements

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19. ABSTRACT

The Royal Australian Navy (RAN) operates several types of combat, minehunting and support ships, which employ steel and copper-nickel (CuNi) piping for mostly low-pressure fluid intake and discharge. The flowing media over time can either cause blockages or destroy the pipe integrity due to marine growth and subsequent corrosion of metal alloy. Maintenance due to corrosion in metallic pipe is therefore a significant issue faced by the RAN. The Defence Science and Technology Organization in collaboration with Tenix is assisting the RAN in investigating the use of Glass-Reinforced Plastic (GRP) piping technology as a solution to existing problems in metallic piping.

Manufactured GRP pipe products are inherently corrosion resistant in many difficult environments and are lighter weight when compared with steel and CuNi piping. In order to gauge the performance a project was initiated to trial the GRP pipe technology on HMAS Anzac. Prior to obtaining approval for a trial the GRP pipe technology was assessed for risk and compliance against technical requirements. The requirements of shock and fire were regarded not essential due to the non-critical nature of selected systems and their locations. However, such requirements are essential for critical systems and therefore would require qualification testing or equivalent on GRP piping.

This paper provides an overview of the selection of ship pipe systems for trial, technical challenges encountered during GRP pipe installation and cost comparison between metallic and GRP piping. Results after six months into the trial indicated the installed GRP piping in HMAS Anzac was in good condition with no report of visible signs of corrosion, condensation or cracking